TIME DEPENDENT EFFECTS

AT THE

FOOT OF THE CHROMOSPHERE

NASA Grant NAGW-253

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The NASA grant NAGW-253 was awarded for a two-year period ending (with an extension) on October 31. It resulted in the publication or submission for publication of ten (10) scientific papers, dealing either with the structure of the upper solar photosphere near the temperature minimum or with numerical methods for solving the radiative transfer equation.

The purpose of the research was to study an apparent failure of empirical models to conserve energy and to resolve inconsistencies in the empirical temperatures at the temperature minimum. The model that was proposed as an explanation of the observed phenomena was a dynamical model, in which acoustic waves generated in the hydrogen convection zone travelled outward with amplitudes increasing nearly exponentially as a function of height. In the temperature minimum region, the amplitudes became sufficiently large for time averages of the fluctuating temperature to be significantly different from the ambient temperature. Thus, the mean temperature was depressed below the ambient temperature, and the apparent temperatures inferred from the time-averaged fluxes of lines in the ultra-violet part of the spectrum were elevated, with the enhancement increasing with the optical frequency of the line transition. These effects, which had been predicted, were indeed found. However, their magnitude was much less than what was needed in order to remove the difficulties in the empirical models.

The failure of the dynamical model is attributed to the assumption that the solar atmosphere is heated by plane waves emerging (horizontally) uniformly over the solar surface and with the energy flux required by the observed emission rate from the chromosphere. This flux gives wave amplitudes that are too small to explain the separation of the empirical temperatures observed in the lines of ionized calcium and magnesium, for example.

The remedy of the dynamical model is to require an energy flux that is large enough to lead to amplitudes for which the apparent temperatures match the empirical line temperatures in the UV lines. Consistency with the observations of chromospheric emission then requires that the emission take place not uniformly over the solar surface but in smaller spatial regions.

This modified dynamical model, which is suggested by the numerical modelling performed with the support of the NASA grant, is in agreement with the observations, which suggest that the solar chromosphere is heated preferentially in magnetic regions, such as magnetic flux tubes. In this case

the mechanical waves that heat the chromosphere are not pure acoustic modes but are slow-mode mhd waves.

Thus, the modified dynamical model of chromospheric heating is based on the generation of slow-mode waves in magnetic regions in the hydrogen convection zone and their propagation ouward along magnetic flux tubes, with shocks forming in the low solar chromosphere. The properties of these waves are such that more energy flux can be generated in the convection zone, less is lost through radiation damping, and shock formation is delayed by the propagation in the flux tube geometry. This dynamical model has an excellent chance of describing the heating of the solar chromosphere. It will be proposed for study under another grant, to be submitted to NASA. Suffice it to note here merely that it is identical to the model discussed at a recent workshop held at Sacramento Peak Observatory, which is credited with having the best chance of explaining the chromospheric temperature structure.

Papers Credited to NASA Grant NAGW-253

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THE EQUILIBRIUM STRUCTURE OF THIN MAGNETIC FLUX TUBES II
(W. Kalkofen, R. Rosner, A. Ferrari, and S. Massaglia),
in preparation.